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December 16, 1957

[redacted] 25X1

Subject: Contract RD-94
Task Order No. 2

[redacted] 25X1

In accordance with Article 2 of the basic contract, there are forwarded herewith two (2) copies of the Monthly Progress Report for November 1957 on Task Order No. 2 of RD-94. This report is UNCLASSIFIED. An additional copy is being held in [redacted] by the project engineer for the use of your personnel while at this location. 25X1

In connection with this monthly progress report the following information is submitted:

Total expenditures to 10-30-57 - $51,415
Outstanding commitments as of 10-30-57 - None
Funds remaining as of 10-30-57 - $ 8,901

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Very truly yours,

[redacted] 25X1

25X1 [redacted]

Manager
Government Contract Adm[redacted] 25X1

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Enclosures

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Monthly Progress Report
November 1957

Task Order No. 2
Contract No. RD-94

Audio Noise Reduction Circuits

The object of this project is to develop a noise reduction circuit suitable for use in separating speech intelligence from a signal containing speech and noise when the speech intelligence is masked by the noise. The proposed method involves a principle which has been used successfully to improve the signal-to-noise ratio in music reproducing or transmission systems.[1] The system used for music contains bandpass filters which pass frequencies over a range of an octave or less. These filters are used at the input and output of a non-linear element. The output of the non-linear elements contain the fundamental, and also harmonics and subharmonics of the fundamental. However, since the pass band of the input and output bandpass filters is no greater than an octave, the harmonics and subharmonics are not transmitted by the system. The function of the non-linear element is to reject all noise signals below a given amplitude or threshold level. The threshold levels of the non-linear devices in each channel can be adjusted so that, in the absence of desired signal, the noise is rejected. When the desired signal is greater than the threshold level, the non-linear elements allow the composite signal to pass. Thus, for passages of recorded music, when the music signal is below the noise level in a given frequency channel, the channel is inoperative, and its output is eliminated from the total output. Since the contribution of this channel to the total output would have been only noise, the over-all noise level is reduced. When the music signal in a given channel is greater than the noise, the channel conducts and allows the composite signal to pass. Thus, a channel conducts only when the desired signal is greater than the noise, and rejects when

1. H.F. Olson, "Electronics," Dec., 1947.

noise alone is present.

In order to apply this method of noise reduction to speech, when the wide band speech signal-to-noise ratio is very low, it was believed necessary to find frequency regions in which the speech amplitude is greater than the noise. Although the long time average spectrum of speech is continuous, and similar in shape to the spectrum of room noise,[2] the short time spectrum of various speech sounds contains regions of maximum energy called speech formants.[3] The assumption that this method of noise reduction should be utilized for speech was based upon the belief that it would be possible to find frequency regions in which the amplitude of the speech formants would be greater than the noise a substantial part of the time.

A study has been made to determine what bandwidths are required in order to obtain speech formant amplitudes above the noise when a wide band speech sample is just intelligible in noise. It is known that for noises with a continuous spectrum it is the noise components in the immediate frequency region of the masked tone which contribute to the masking.[4] When a very narrow band of noise is used to mask a pure tone, the masking increases as the bandwidth is increased until a certain bandwidth is reached. After this, as the bandwidth is increased, the amount of masking remains constant. This bandwidth at which the masking reaches a fixed value is termed the critical bandwidth.[5] Measurements have been made using filters which were

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2. H. Fletcher, "Speech and Hearing on Communication," Van Nostrand Co., Inc., New York, 1953 (see Figures 61 and 70).

3. Op.cit. chap. 1.

4. L.L. Beranek, "The Design of Speech Communication Systems," Proc. IRE, Vol. 35, pp. 882, Sept., 1947.

5. N.R. French and J.C. Steinberg, "Factors Governing the Intelligibility of Speech Sounds," Jour. Acoust. Soc. Amer., Vol. 19, Jan., 1947, (See Figure 7).

both narrower and wider than the critical bandwidth. Both pure tones and speech mixed with continuous spectrum type noises have been studied. The results of this study show that, for the narrowest permissible bands which can be used to pass speech formants, the number of times the speech formant amplitude in a given band exceeds the noise is small. Also, in these bands, the speech amplitude is never considerably greater than the noise. Since very narrow bandwidths are required to reduce the noise below the signal, the number of bands required to cover the speech spectrum is quite large. There was no satisfactory way of evaluating the effect upon speech intelligence of small contributions from many narrow bands without building a many channeled circuit and evaluating it. A complete multi-channel system has been developed in order to determine the effectiveness of this method of improving speech intelligibility in noise. The multi-channel system developed contains 110 channels covering the frequency range from 170 to 3200 cps. The bandwidth and the threshold level of each channel is adjustable. The 110 channels are arranged on 11 chassis with 10 channels on each chassis.

During November the 11 band pass filters were completed and installed in their respective chassis. The characteristics of those band pass filters are shown in Figure 1. A block diagram of the complete noise reduction system is shown in Figure 2. A block diagram of one of the 11 chassis is shown in Figure 3. The complete system has been installed in the racks. The 110 adjustable narrow band filters had been previously adjusted to be 6 db narrower than the critical bandwidths of the ear. Under this condition the noise reducer had not been as effective as it had been when the 110 bands were adjusted 3 db narrower than the critical bands. From a preliminary test, the addition of the 11 new band pass filters and volume compressors appears to have improved the performance of the noise reducer. Several different test conditions will be tried in order to completely evaluate the noise reducer in its present form.

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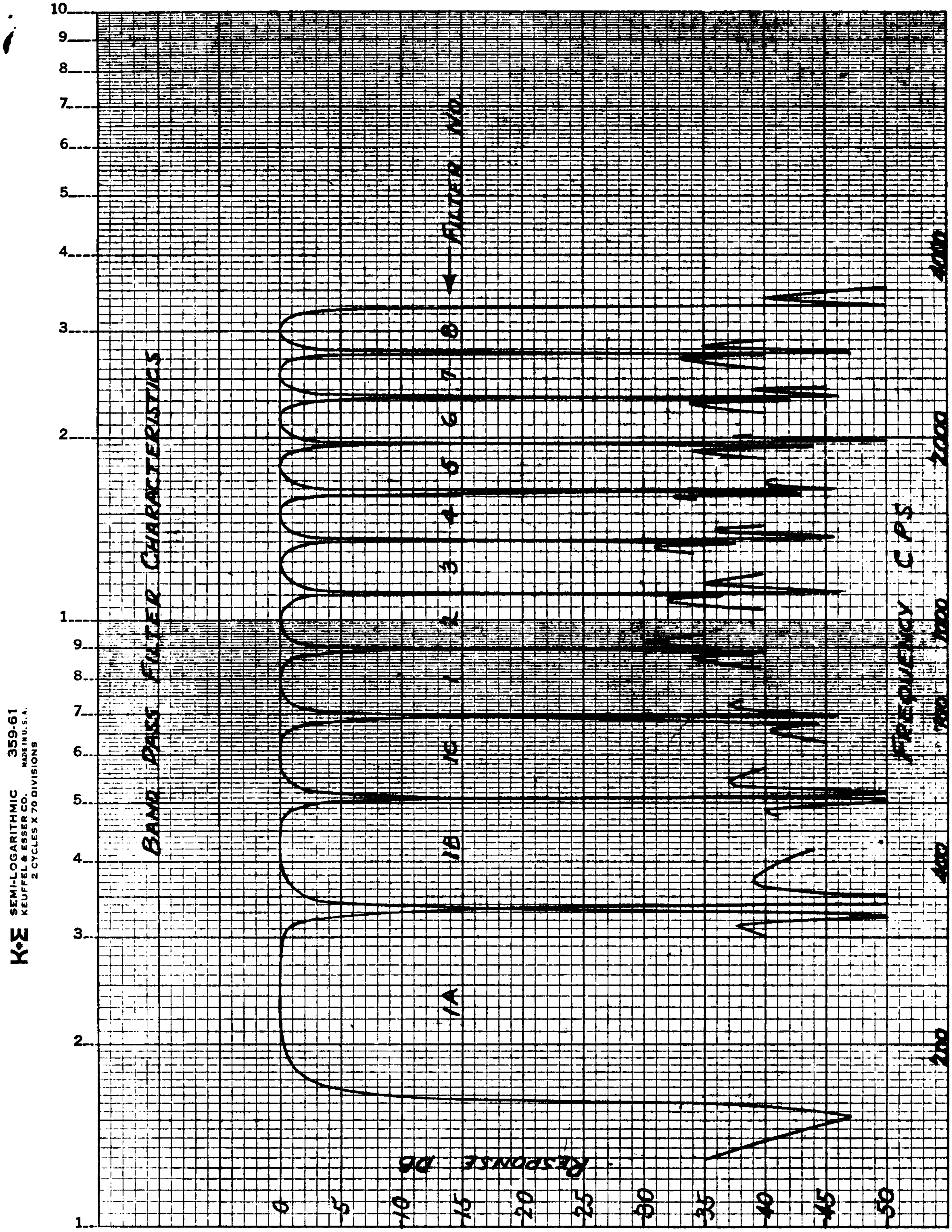
December 6, 1957


BAND PASS FILTER CHARACTERISTICS
FILTER NO.
8
7
6
5
4
3
2
1
1C
1B
1A
FREQUENCY CPS
4000
2000
1000
700
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RESPONSE DB
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K+E SEMI-LOGARITHMIC 359-61
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 70 DIVISIONS

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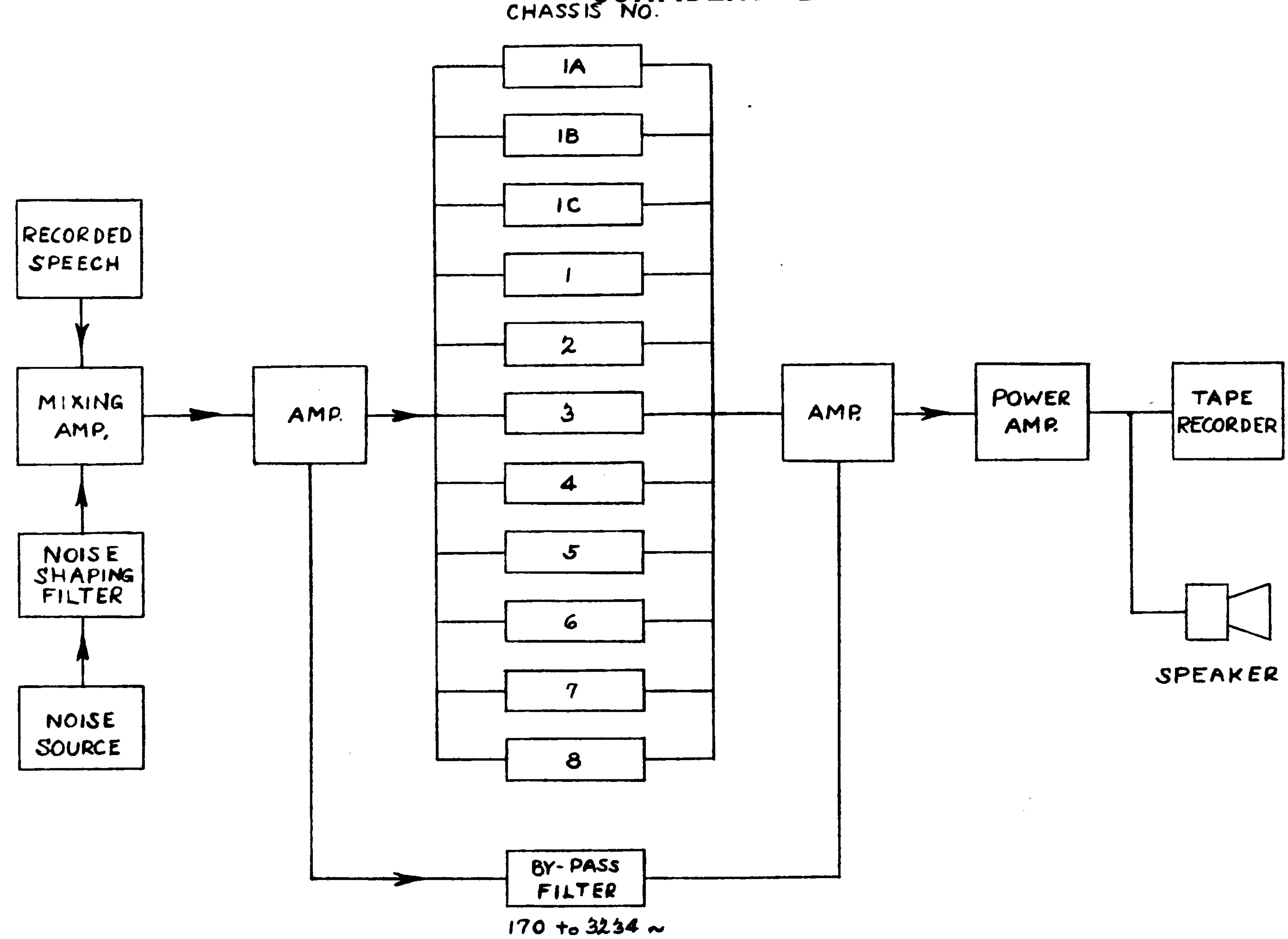

FIG. 2 BLOCK DIAGRAM OF NOISE REDUCER

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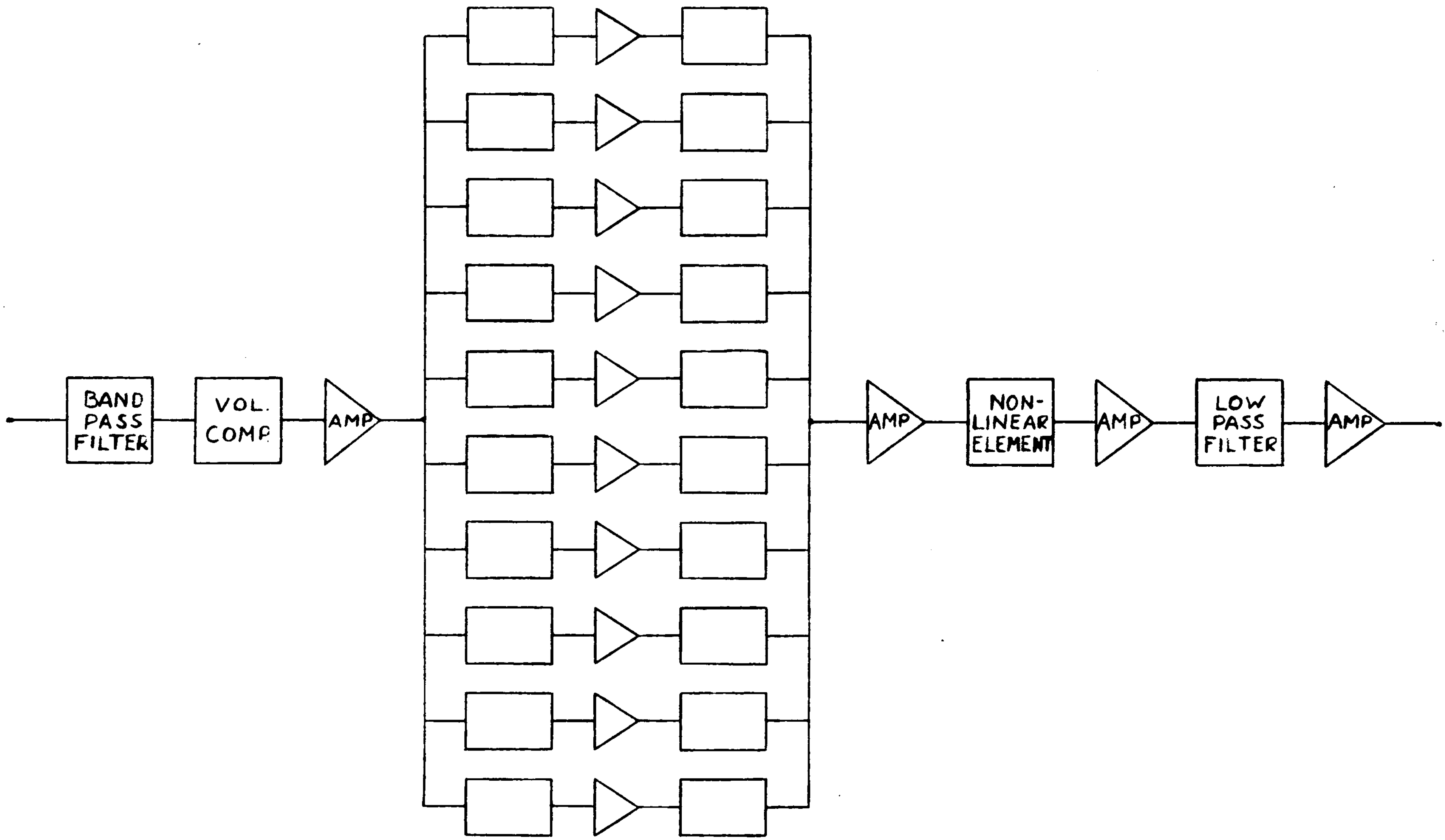

FIG. 3 BLOCK DIAGRAM OF ONE NOISE REDUCER CHASSIS

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